After 100 Years of Forest Management: "The North Kaibab"

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Abstract. Assessment of 100 years of forest overstory data on the North Kaibab Ranger District reveals significant changes in overstory character and structure. Evaluation of early written observations by explorers, surveyors and naturalists indicate that tree densities of the 1850s were low and the forest floor had minimal fuel loads. Recent research in restoration ecology on the district indicates pre-European settlement tree densities were originally 30–60 trees per acre. Analyses of surveys completed in 1910, 1955, 1977, and 1993, reveal that tree densities below 6" diameter at breast height (dbh) have increased from 107 trees per acre in 1910 to over 900 today. Number of trees above 6" dbh have increased from 45.3 trees per acre in 1910 to 115 in 1993. These increases have occurred with concurrent managed harvests of over 1.4 billion board feet of timber from the 1920s through 1994. Analysis of current conditions reveals 25% of the forest is potentially at high risk, and over 65% at potentially medium to high risk of ecosystem loss to insect and disease and/or wildfire. New ecosystem management guidelines, especially in regards to threatened and endangered species, could contribute to increased densities on the North Kaibab.

Key words: Ecosystem analysis, forest resource assessment, Geographic Information System, Kaibab National Forest, *Pinus ponderosa*, ponderosa pine, stand density index, tree densities.

In 1893, Congress authorized the establishment of the Grand Cañon Forest Preserve, a high plateau forest located on the north rim of the Grand Canyon in Arizona (U.S. Forest Service 1968). In 1906, President Theodore Roosevelt, a hunting enthusiast, designated the Kaibab Plateau area as the Grand Canyon Game Preserve. In 1908, the area became part of the larger Kaibab National Forest, extending south beyond Williams, Arizona. In 1919, the southern extremity of the Kaibab Plateau, which abuts the northern rim of the Grand Canyon, was made part of the Grand Canyon National Park (U.S. Forest Service 1968, Baker et al. 1988).

Today, after 100 years, the U.S. Forest Service continues to manage over 655,000 acres of shrubland, woodland, ponderosa pine, mixed conifer, and spruce-fir forests on the Kaibab Plateau. The Plateau is one of four districts on the Kaibab National Forest and is designated the North Kaibab Ranger District (NKRD) (Fig. 1).

The NKRDs first forest management treatments came at the direction of Dr. Bernard Fernow, the first Chief Forester of the Division of Forestry, then in the Department of the Interior. Dr. Fernow considered the ponderosa pine regions of Arizona to be well suited for timber production (Fernow 1897).

NKRD has passed through an ever evolving, but reasonably stable, management philosophy of the U.S. Forest Service for 100 years. It was characterized as "wise use," by Gifford Pinchot, the first Chief Forester of the U.S. Forest Service, and has since adopted concepts of multiple use management, and derivations thereof, including integrated resource management, and currently ecosystem management (West 1992).

This paper is drafted from a more comprehensive technical report (Garrett 1995), which describes U.S. Forest Service management on the Kaibab Plateau over the last 100 years and the changing management direction to both biophysical resource and socioeconomic infrastructure in the region. We address here only one aspect of ongoing assessments noted; the changing ponderosa pine overstory on the North Kaibab. Included are discussions of the dynamics of the overstory from 1893–1993, changing silvicultural practices, and probable implications of increasing tree densities. Finally, we pose questions regarding newly implemented ecosystem management guidelines and their potential implications.

Assessment Procedures

Our evaluations on the North Kaibab Ranger District is an attempt to examine several important components of the forest ecosystem. The ponderosa pine forest overstory is the most dominant resource in this forested landscape. Management of this overstory is under intense controversy, implying the need for improved knowledge of how it is changing, and the implications of these changes.

Because approaches to ecosystem management should attempt to analyze biophysical resources through time and space, we utilized a geographic information system as a tool for much of our comparative analysis. This required, in some instances, development of algorithms to compare, for example, the 1910 Kaibab forest reconnaissance (Lang and Stewart 1910), to the 1993 forest assessment (U.S. Forest Service 1994). Due to differing sampling methodologies used in several overstory surveys from 1910 and

Fig. 1. The North Kaibab Ranger District (NKRD) in Arizona.

1994, derived measurements are not statistically comparable. This paper, therefore, presents descriptive comparisons of the 1910, 1955, 1977, and 1993 resource surveys, contrasting variables in the databases. Complete descriptions of original survey procedures, and procedures for conforming different databases for analysis in GIS, can be found in Garrett (1995) and Ellenwood (1994).

A Changing Forest Overstory

To evaluate a century of changes in the North Kaibab Ranger District forest overstory, we first describe the forest's general character in the pre-European settlement period of the mid–1800s. We then describe changes in the overstory through this century.

Although Native American occupation and Anglo-American visitations to Arizona's ponderosa pine forests predated the 1800s period, written observations of Arizona's ponderosa pine forests do not appear in the literature until the mid–1800s (Cooper 1960). Collectively, there are many written descriptive observations on these ponderosa pine forests during the late 1800s. The observations recorded by early naturalists and explorers are very similar, and afford valuable descriptions of the forest character and structure.

For example, in 1858, Edward Beale, a surveyor for the transcontinental railroad traveling south of the Grand Canyon recorded the following:

> "A vast forest of gigantic pines, inserted frequently with open glades, sprinkled all over with mountains, meadows, and covered with the richest grasses, was traversed by our party for many days. We came to a glorious forest of lofty pines, through which we have traveled ten miles. The country was beautifully undulating, and although we usually associate the idea of barrenness with the pine regions, that was not so in this sense; every foot being covered with the finest grass and beautiful grassy glades extending in every direction. The forest was perfectly open and unencumbered with brush wood, so that the traveling was excellent" (Beale 1858).

And in the classic "Physical Geology of the Grand Canyon Region," Dutton (1882) describes the ponderosa pine forests of the Kaibab Plateau as follows:

> "The trees are large and noble in aspect and stand widely apart, except in the highest parts of the plateau where the spruces predominate. Instead of dense thickets where we are shut in by impenetrable foliage, we can look far beyond and see the tree trunks vanishing away like an infinite colonnade. The ground is unobstructed and inviting. There is a constant succession of parks and glades, dreamy avenues of grass and flowers winding between sylvan walls, or spreading out in broad open meadows. From June until September there is a display of wild flowers which is quite beyond description" (Dutton 1882).

By the first decade of the 1900s many of the southwest forest areas had been surveyed by professional foresters. Involved with these surveys was

Theodore Woolsey (1911), who coordinated a survey for forests of Arizona and New Mexico. The survey determined average stand conditions as well as stand conditions for the most dense stands surveyed in eight southwestern national forests in the 1911 period. He also provided some of the first technical descriptions of the pre-settlement pine forests of the Southwest, as follows:

> "A true park-like stand made up of scattered groups of from 2 to 20 trees usually connected by a scattering of individuals. Openings are frequent, and very great in size within the forests. Open parks of large extent whose origin may be due to peculiar soil conditions such as hardpan, or in other cases periodic flooding" (Woolsey 1911).

The first overstory survey of the North Kaibab ponderosa pine forest ecosystem was conducted in 1910 (Lang and Stewart 1910). The 1910 survey mapped out 353,938 acres of forested land and 5,197 acres of grassland, of which 266,042 acres of forest and 4,556 acres of grassland fall within the current boundary of the Kaibab National Forest (Ellenwood 1994). Between this first decade and the fifth decade of the century, analysis of the overstory was primarily captured in working circle plans and area management plans of the forests (U.S. Forest Service 1988). At the mid-century, sampling based continuing forest inventories (CFI) were established on the North Kaibab (U.S. Forest Service 1988). These efforts were to be repeated every 10 years to identify changes in character and structure due to both natural and anthropogenic phenomena.

In the 1970s, compartment exams were implemented to quantitatively evaluate stratified stand conditions and to produce silvicultural prescriptions (U.S. Forest Service 1994). In the early 1980s, terrestrial ecosystem surveys were introduced, and in 1985 there was an interest to increase area resolution and include other resources such as understory plant diversity and forest floor conditions (U.S. Forest Service 1988). Compartment exams became stand exams, to facilitate integrated stand management (ISM). This prompted the introduction of stand level assessments referred to as stage 2 stand inventory procedures (U.S. Forest Service 1993). Information from several of these sources has been evaluated to assess overstory changes through time. We have chosen to focus on trees per acre as the descriptor of change.

Figure 2 presents a 3-picture sequence from a permanent photo point of changes in forest overstory on the Fort Valley Experimental Forest, located in the southwestern ponderosa pine type near Flagstaff, Arizona, and now under continuous study for over 75 years (1909–1990). Pictures a, b, and c contrast 75 years of change in the overstory. In 1909, less than 50 trees per acre above 6" dbh existed on the site. In 1990, over 160 trees per acre greater than 6" dbh existed in the area (Covington and Moore 1994).

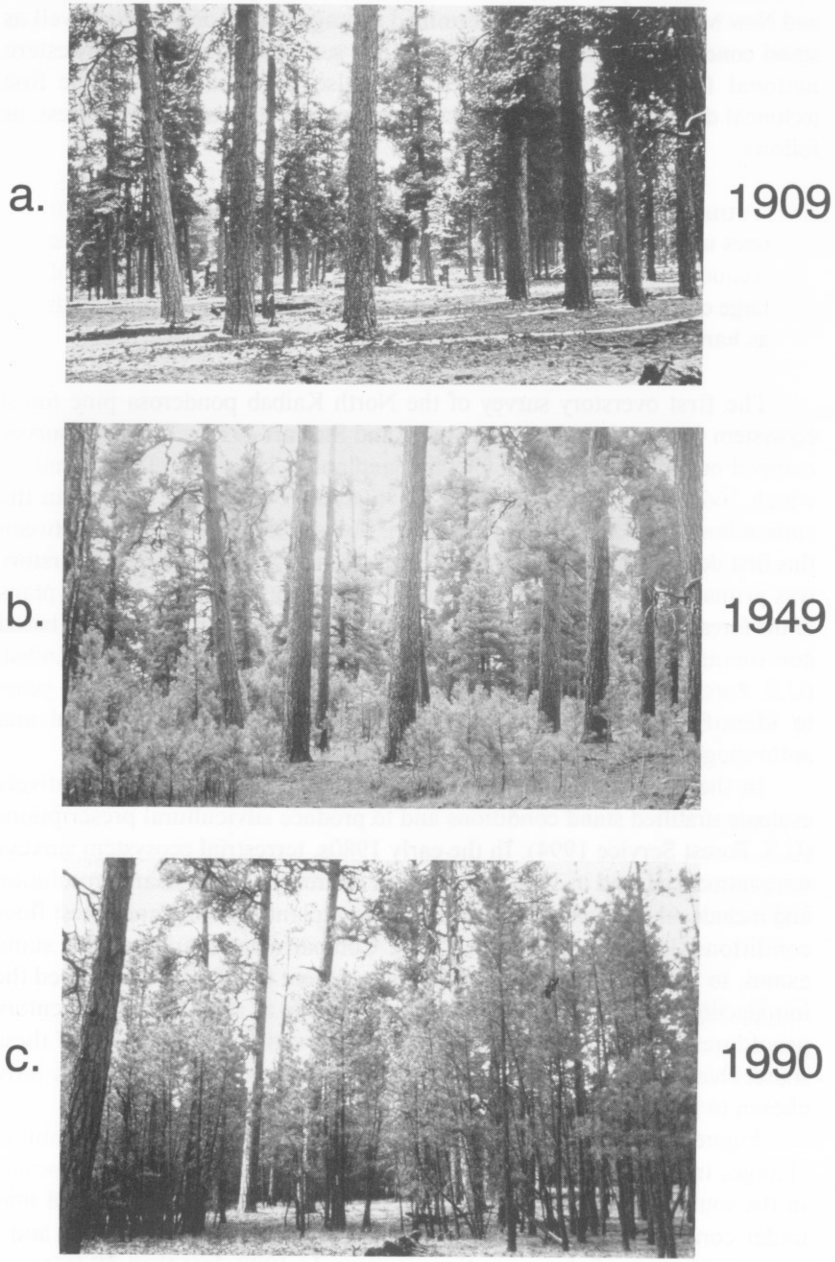

Fig. 2. Changes in forest overstory from a permanent photo point, Fort Valley Experiment Forest, Coconino National Forest, Arizona: 1909–1990.

Several forest researchers since the 1950s have evaluated changing ponderosa pine overstories of the Southwest, including Weaver (1951), Cooper (1960), White (1985), Covington and Sackett (1986), Covington and Moore (1994), and Ellenwood (1994). These studies have linked critical management actions of wildfire suppression, public land grazing, and tree harvests to current modified overstories and increasing tree densities now apparent across the entire range of this ecotype.

Restoration ecology research on the North Kaibab by Covington and Moore (1992) characterizes the presettlement forest prior to 1882 as having approximately 55.9 trees per acre. Descriptions provided in early writings, and restoration ecology research since the 1950s, can be used to characterize the pre-European settlement ponderosa pine forest as follows:

> "The southwest ponderosa pine forest overstory was most likely a fire driven ecology, with tree densities controlled by wildfire regimes moving across the landscape at 3 to 12 year intervals. This resulted in removal of most ground fuels and extensive suppression of regeneration. Resulting overstory was a mosaic of low density stands dominated by larger diameter trees located in clumps of 2 to 30 and averaging 30 to 50 trees per acre."

Overstory Inventories: 1910–1993

Figure 3 presents survey comparisons of changing character and structure of the North Kaibab's forest overstory from Lang and Stewart's first survey in 1910 through the 1993 forest assessment (U.S. Forest Service 1994). Trees per acre by diameter class are the comparative factor derived from these surveys. Trees per acre contribute to development of important measures of competition in forest overstories, including basal area and stand density index.

The comprehensive reconnaissance of the North Kaibab forest by Lang and Stewart (1910), reported the average trees per acre at 152.4 (Ellenwood 1994). The average number of trees below 6" dbh was 107 and above 6" dbh was 45.3. Most of the 6" dbh and larger trees lay between 6" and 18" dbh. Only 9.8 trees per acre were greater than 20" dbh. And, although there was a large tree component on the Kaibab Plateau, on average only 1.4 trees per acre existed over 30" dbh.

Studies have demonstrated that the mortality of ponderosa pine increases with both diameter and stand density (McTague 1990). Larger trees, normally the product of age, have greater susceptibility from such damaging agents as lightning, wind, crown fires, bark beetles, and other agents (Pearson 1950, Schubert 1974). Both Pearson (1940, 1950) and Schubert (1974) have associated higher mortality in this species with larger (greater than 28" dbh) and older trees.

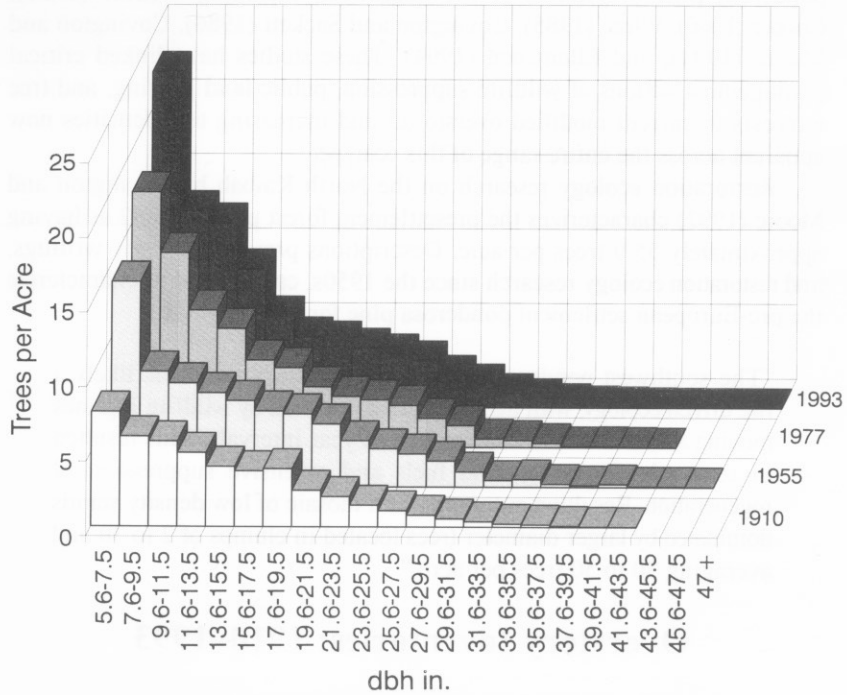

Fig. 3. Trees per acre in the North Kaibab ponderosa pine type: 1910–1993.

The fact that only 43.5 trees per acre existed above 6" dbh in 1910 lends credibility to the argument by restoration ecologists that presettlement ponderosa pine forests were dominated by approximately 30–60 trees per acre (Covington and Moore 1992). The fact that livestock grazing and wildfire suppression were introduced to the southwest forests in the 1870–1910 period, allowed four decades for recruitment of new trees in the 1 to 6" dbh classes, and movement of trees existing in the 3 to 6" dbh classes into the 6 to 8" diameter classes (U.S. Forest Service 1988). If fire had continued in these ecosystems, it is likely that many of the trees 0 to 6" dbh would not have survived. Further, even fewer trees would have grown into the 6 to 8" dbh classes, putting the total number of trees above 6" dbh at 20–35, instead of 43.5.

The 1955 continuous forest inventory (CFI) revealed that the 1910, 3 to 6" dbh trees, had grown significantly so that the average number of trees above 6" dbh was now 73 trees per acre, compared to 45.3 in 1910. Trees below 6" had also increased radically, from 107 to 422 trees per acre.

The 1977 forest survey revealed a continued expansion of the forest above 6" dbh (Fig. 2). Although recruitment into dbh classes above 6" had increased, these increases were partially offset by expanded timber stand improvement cuttings, thinnings and commercial harvests, as well as mortality in larger trees. The overall average number of trees above 6" dbh increased to 92 per acre as compared to 73 trees in 1955. The gradual movement of the 1910 6 to 12" dbh classes into higher diameter classes is apparent in Fig. 3.

Tree harvest levels increased during the 1950s and 1960s to approximately 60 million board feet per acre by the late 1970s (U.S. Forest Service 1993). These harvest levels continued until 1991 and have since declined due to increasing opposition to management activities on federal forest lands. However, in spite of these harvests, the 1993 assessment of trees per acre above 6" dbh demonstrates continued gains in the 6 to 15" and 20 to 30" dbh classes. Further, the total number of trees above 6" dbh continued to increase to an average of 115 trees per acre.

Figure 4 characterizes by diameter class the net change in trees per acre above 6" dbh between the 1910 and 1993 surveys. All size classes from 6 to 30" dbh have increased in stocking in 80 years, moving from a total of 43.5 trees per acre in 1910 to 115 trees in 1993.

Since no extensive survey of the North Kaibab area existed prior to 1850, a direct comparison of the 1993 stocking levels above 6" dbh cannot be made to pre-European settlement forest conditions. However, using Woolsey's (1911) assessments and restoration ecologists' definition of pre-European settlement forest conditions, the 1993 inventory data indicate that forest overstory densities above 6" dbh on the North Kaibab today are somewhere between 250 and 350% greater than densities in the early 1800s. Increased densities below 6" dbh also occurred. Whereas Lang and Stewart (1910) recorded an average of 107 trees below 6" dbh in 1910, 422 trees were recorded in 1955 and 943 in 1993.

Further, it is difficult to ascertain what average maximum stocking potential can be reached below 6" dbh. Examples exist on several forests where stocking below 6" dbh across stands can exceed 1,500 trees per acre (Pearson 1950, Schubert 1974, Covington and Moore 1994). Given a reoccurrence of optimal regeneration conditions as witnessed in 1919, significant increases could continue to occur in these diameter classes (Pearson 1950).

Trees above 6" dbh in diameter are also likely to increase unless more intensive management actions are taken. As noted in Fig. 4, most of this increase has occurred between 6" and 15", with additional increases occurring between 20" and 30" dbh. When the entire plateau is considered, these diameter classes now contain millions more trees than they did in 1910.

The data indicate that over the century only a slight increase has occurred on the Plateau in number of trees above 30". On some acres where more intensive harvest or high mortality has occurred there have been reductions

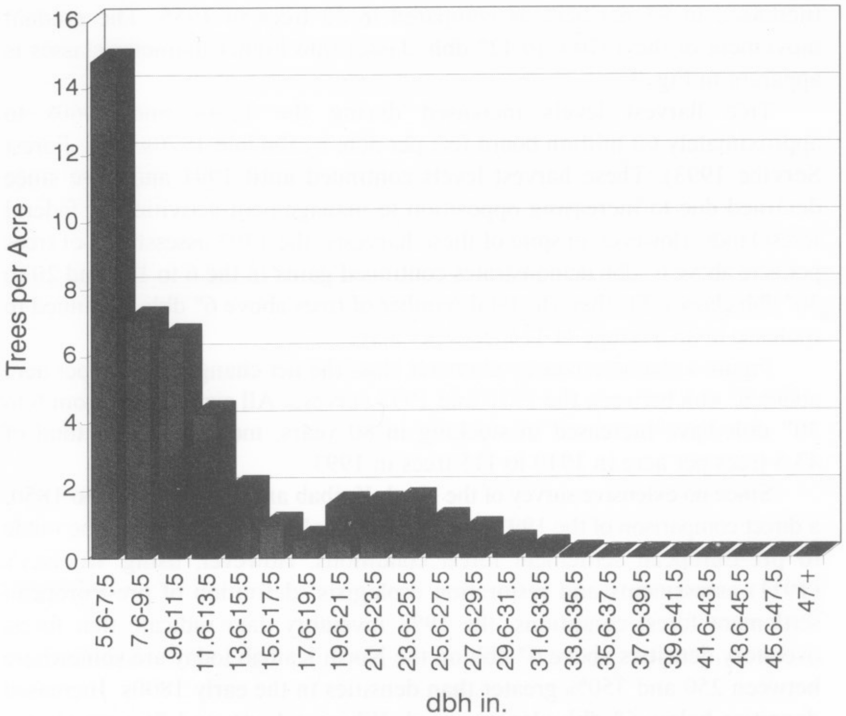

Fig. 4. North Kaibab ponderosa pine type: Net change in trees per acre, 1910–1993.

in very large trees per acre. These are obviously balanced by acreages where numbers of trees above 30" have increased due to ingrowth.

The greatest concern revealed by these comparative data is that there are greater than average increased densities continuing in diameter classes 6–15" dbh and 20–30". These trees will continue to grow, expanding both their crown and root systems. As they express greater dominance in capturing increasing levels of soil moisture, nutrients and solar insolation, they will afford a significant environmental threat to all old large trees as well as herbage production (Schubert 1974, Clary 1978, Covington and Moore 1994).

Overstory Management, Harvests and Mortality

The type of silvicultural management practiced is always diverse for different forest types and differing management objectives. The general harvest practice on the North Kaibab for the first half of this century was to remove overmature, diseased, deformed, and mistletoe trees. These individual selection removals resulted in an average of 1,500 board feet per acre being harvested, during which time the average wood volume rose from 4,000 board feet per acre to 9,600 board feet per acre across the plateau (U.S. Forest Service 1993).

Prior to 1946, removals were minimal from the North Kaibab (U.S. Forest Service 1993). There were several small mills which only impacted localized areas. In 1946, Whiting Brothers opened a small mill in Fredonia, eventually constructing a large capacity mill in 1948. After 1948, they were the principal buyer of forest products from Forest Service lands on the North Kaibab.

In the mid-1980s, ISM was implemented on the plateau, which basically focused on stand specific objectives. The timber management plan in effect at that time recommended even-aged management. Most of the ISM treatments followed even-aged regeneration prescriptions such as shelterwood and seed-tree cuts.

On seed-tree cut sites, 10 to 13 trees per acre in the 18 to 24" dbh size class were left for a seed source and site protection. Smaller trees were cut to prepare the site for new regeneration. Heavier cutting occurred in areas with severe dwarf-mistletoe infections, which often left fewer seed trees and required fill-in planting to assure adequate and timely regeneration.

From 1976 to 1993, a total of 33,661 acres of pre-commercial thinnings were conducted to reduce stocking of smaller trees (U.S. Forest Service 1993). However, this equates to only one pre-commercial thinning for each rotation of trees, which is inadequate to control increased stocking of small trees. Schubert (1974) viewed this increased stocking as contributing to increased insect and disease infestations and eventually increased losses to wildfire.

The primary disease attacking ponderosa pine on the Plateau is dwarf mistletoe. It too existed throughout the range of ponderosa pine in the presettlement period and today is one of four major causes of mortality in southwestern ponderosa pine overstories (Schubert 1974). On trees not killed, it is responsible for about 15% reduction in growth. It is more pervasive in dense stands under increased stress.

Lightning strikes and associated wildfire have always been a prominent natural mortality factor in this ecosystem. However, the type and level of risk and impact from lightning and wildfire has changed due to increased tree densities. In pre-European settlement times, lightning was the most critical agent in causing loss of old mature trees (Woolsey 1911, Pearson 1950).

Wildfire was a ground-based phenomenon placing only regeneration at risk. Current wildfires, however, are more intense due to increased densities, which provide both greater ground fuel loads and fuel ladders (Covington and Moore 1994).

Reductions to the forest overstory also result from commercial harvest of wood products. In general, under existing sustained yield policy guidelines, forest managers are to implement removals only to a level that does not inhibit the ability of the forest to provide a continued sustained flow of wood products (U.S. Forest Service 1994). Figures 5 and 6 illustrate where commercial harvest removals have occurred on the NKRD since its establishment. In total, over 1.4 billion board feet of commercial products have been removed since the early 1920s (U.S. Forest Service 1993). Figure 5 is a graphic of all areas where selection harvest treatments were applied. The dark areas represent stands that were harvested, thinned or treated from 1965 to 1984, with removals accounting for approximately 1,500 board feet per acre (U.S. Forest Service 1994).

In the mid-1980s, under new silvicultural approaches of integrated stand management and integrated resource management, shelterwood and seed tree harvests were established removing an average of 3,500 board feet per acre in treated areas (U.S. Forest Service 1994). In Fig. 6, treatments are represented by rectangular cutting units interspersed, primarily on a north/south axis in the central portion of the forest. Shelterwood harvests, applied with integrated resource management in the mid-1980s, have now changed to ecosystem management, which will utilize developed standards and guidelines for implementation. Whereas the traditional focus of multiple use and integrated resource management was on management of the forest for use, such as commodity products, services and amenity values, ecosystem management focuses not just on traditional resource uses, but also on intrinsic values of the land including biodiversity, health and sustainability.

Implementation of Ecosystem Management and Protection of Biodiversity

As noted, one focus of ecosystem management is protection and maintenance of biodiversity in an ecosystem. This includes development of standards and guidelines for activity implementation. In general, these guidelines act as constraints, both temporally and spatially on any activities that might be proposed for areas within the forest ecosystem.

Examples of standards and guidelines associated with protecting biodiversity, are those related to creating protective habitat for the sensitive northern goshawk, and endangered Mexican spotted owl. However, constraints proposed as developed guidelines could also severely impact potential restoration treatments to reduce increasing tree densities in these critical habitat areas. The total number of acres withdrawn is significant.

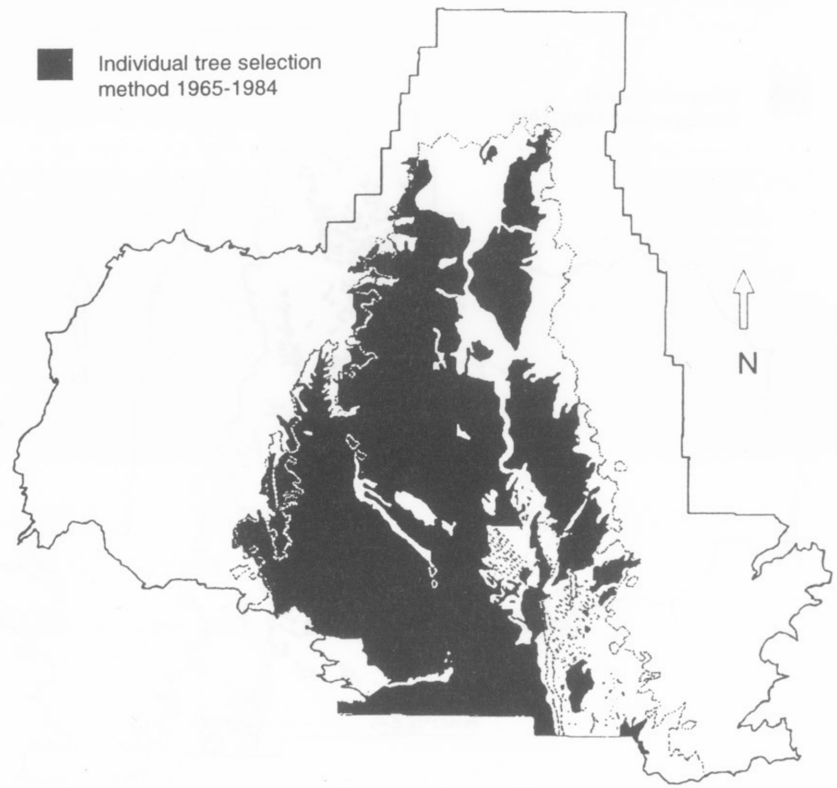

Fig. 5. Areas of the North Kaibab Ranger District (NKRD) harvested using the individual tree selection method: 1965–1984.

Figure 7 relates Forest Service designated critical habitat for the Mexican spotted owl and Forest Service northern goshawk territories (U.S. Forest Service 1994, U.S. Department of the Interior 1995).

The northern goshawk's existence on the plateau has long been noted. Rasmussen's (1941), flora and fauna assessments of the late 1930s, characterized the northern goshawk population to be sparse and have spotty distribution in the yellow pine and spruce-fir forested areas of the plateau. He noted that:

> "The Goshawk is a bird of considerable importance in the interactions of this community. Only its scarcity prevents it from being a major influence. Although Arizona is considered to be the extreme southern tip of their breeding range, birds were seen during

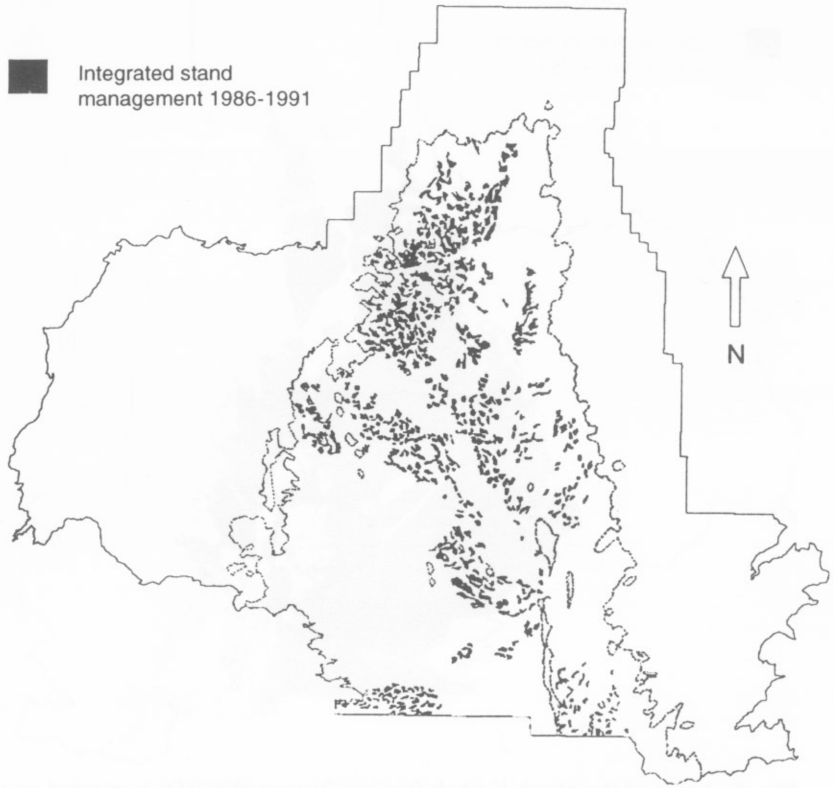

Fig. 6. Areas of the North Kaibab Ranger District (NKRD) harvested under integrated stand management: 1986–1991.

all months over three summers of study. It was estimated in 1931 that there was one Goshawk per five sections." "Observation of food habits showed that adult hawks feed mostly on birds, but caught rabbits, the mantled ground squirrel, the Fremont chickadary and the Kaibab squirrel" (Rasmussen 1941).

Today, the Forest Service is managing for two northern goshawks per four sections (2,880 acres), or one bird per 1,440 acres. This is approximately twice the number of birds by area estimated by Rasmussen (1941) (one per 3,600 acres). Surveys to date have located eighty nesting pairs on 240,000 acres, or one bird per 1,500 acres. Although there is no effective method to compare the accuracy of bird counts in the two assessments, one

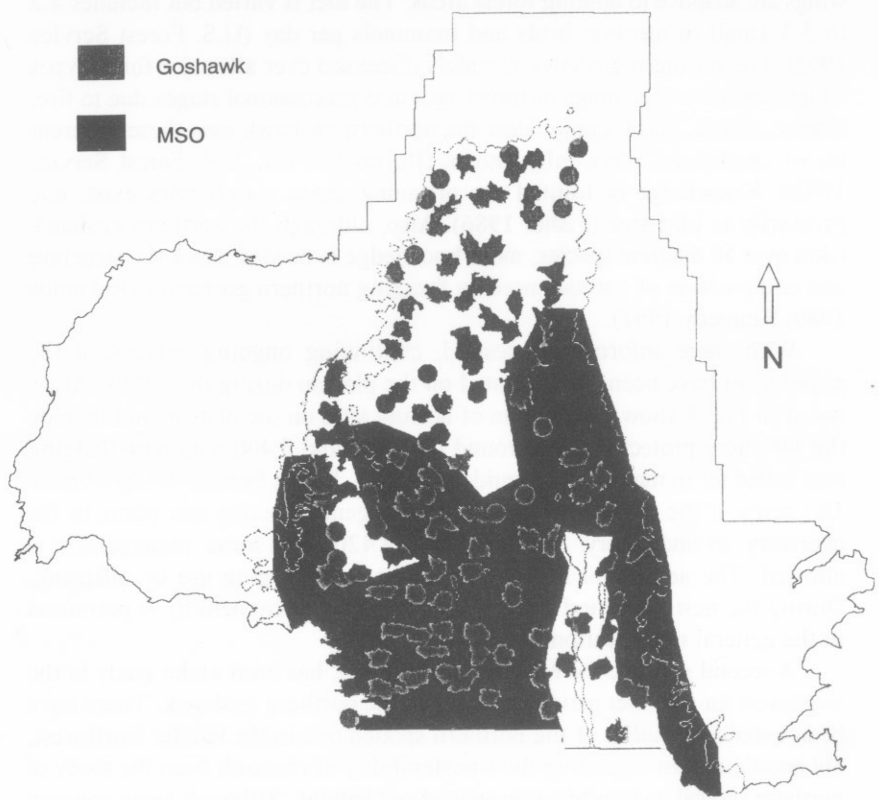

Fig. 7. Northern goshawk territories and Mexican spotted owl critical habitat on the North Kaibab Ranger District (NKRD).

might assume current surveys to be more accurate. In 1982, the U.S. Forest Service and Fish and Wildlife Service classified the northern goshawk as a sensitive species, requiring further study (U.S. Forest Service 1994). Increased research since that time includes work by Reynolds (1989), Crocker-Bedford and Chaney (1988), and Kennedy (1989), who have developed energy, nesting and feeding information on the species. Research by Crocker-Bedford and Chaney (1988), was extrapolated temporally and spatially to conclude that the northern goshawk population was declining, and that overstory removals were a probable factor in species decline. Reynolds (1989) concluded that northern goshawks were at their social density peak on the North Kaibab. A comparison of the Rasmussen (1941) assessment and current surveys would indicate increases in bird density.

The northern goshawk is the largest member of the Accipiter family, and occupies coniferous and deciduous forest types. Its long tail and short round wings are adaptive to hunting forest areas. The diet is varied but includes 4.2 to 5.3 small to medium birds and mammals per day (U.S. Forest Service 1992). The northern goshawk is widely dispersed over all major forest types which contain a wide range of forest ages and successional stages due to fire, disease, insects, and logging. How the northern goshawk uses these different forest conditions is not fully known (Reynolds 1989, U.S. Forest Service 1992). Knowledge of limited use of young dense stands does exist, due primarily to bird size (Fisher 1986). Also, although the northern goshawk takes over 50 different species, more knowledge is needed about the structure and composition of habitats used by foraging northern goshawks (Reynolds 1989, Kennedy 1991).

With more information desired, continuing ongoing surveys of the population have been implemented on the plateau during the 1990s. Areas noted in Fig. 7 show distribution of nesting sites on the plateau and include the 600 acre protected zone around the nests and 5,400 acre post-fledging area called for in management guidelines (U.S. Forest Service 1992). Within 180 acres of the 600 acre zone, little management action can occur in the overstory or understory. In the remaining 420 acres some management is allowed. The additional 5,400 acres is for post-fledging use by offspring. During the nesting period little overstory management activity is permitted in the general nest locations.

A second species, the Mexican spotted owl, has been under study in the Southwest for a shorter period of time than the northern goshawk. There have been extensive studies of the northern spotted owl in the Pacific Northwest, but questions exist regarding the transferability of research from the study of northern spotted owls to Mexican spotted owl habitat. Although some concern existed over the need for better definition of the Mexican spotted owl's critical habitat in the Southwest, its listing in 1994 precipitated the requirement for critical habitat establishment. That critical habitat is pervasive, especially in the recommended requirements for species nesting, fledging and foraging requirements (U.S. Department of the Interior 1995). Figure 7 shows the area on the Kaibab Plateau which was proposed in 1995 as critical habitat for the Mexican spotted owl (U.S. Department of the Interior 1995). Vegetative types represented include pinyon-juniper, canyons dominated by mixed species hardwood and softwood, ponderosa pine, and mixed conifer and spruce-fir type forest ecosystems. Most of the area is ponderosa pine and mixed conifer cover types.

Research continues on the Mexican spotted owl in the Southwest and the Kaibab Plateau. Also continuing are inventories which locate adult individuals or pairs and/or nest sites. Between 1990–1994 numerous intensive inventories of the entire Kaibab Plateau were conducted to locate nest sites and/or adults within the habitat. These intensive surveys have failed to locate Mexican spotted owl nest sites (J. R. Ellenwood 1996, Kaibab National Forest, Williams, Arizona, personal communication).

A review of scientific literature to date do not document sightings of the Mexican spotted owl on the plateau. Rasmussen (1941) in his intensive study failed to identify the species on the plateau over a 3–year period.

Implications of Current Management Direction

We have evaluated changes in the North Kaibab overstory through the period 1900–1994, illustrating increasing densities in trees smaller and larger than 6" dbh. There have been significant removal of overstory by harvests, thinnings, and natural mortality. Documented harvest activity from the early 1900s to 1993 have accounted for over 1.4 billion board feet of harvests. In addition, many trees have been lost to natural mortality. However, recruitment of new trees through regeneration has greatly exceeded removals and natural losses from the overstory, so much so, that average number of trees per acre above 6" dbh has risen from 45.3 in 1910 to 115 in 1993, and trees below 6" dbh have increased from 107 to over 900 per acre.

The question of what level of tree density is desirable is a social issue. Any public land desired future condition will create an array of social benefits and costs or tradeoffs. Forest managers and the general public must evaluate these tradeoffs to determine the preferred management direction.

Forest health specialists, fire ecologists, and conservation biologists have determined that increasing densities in western ponderosa pine forest ecosystems are degrading these ecosystems and placing increased acreages at greater risk to insects and diseases and destructive wildfires (Sampson and Adams 1994). In general, increased densities reduce forest health and diversity and create ecosystem conditions that are not sustainable.

Several authors cite the following conditions to result from increased densities (Brown et al. 1974, Schubert 1974, Rogers et al. 1984, White 1985, Covington and Moore 1994).

- reduced tree growth
- stagnated nutrient cycles
- increased insect and disease
- decreased forage
- increased fuel loads
- decreased native flora
- increased crown wildfire
- decreased on-site water

These specialists and others have noted increased tree densities to cause greater risk to the entire forest ecosystem. Stand density index is one measure used to evaluate overstory densities and the potential threats they impose on the forest ecosystem (Schmid et al. 1994). Schmid et al. (1994) proposed using three growing stock levels as guides for managing mountain pine beetle in the Black Hills of South Dakota.

Generally, three levels of density are proposed by Schmid et al. (1994), as interpretive guidelines for ecosystem risk: 0–34, 34–54, and 54% of SDI. SDIs below 34 are not considered threatening. That is, densities at and below this level do not seem to create unhealthy tree competition and measurable degradation to the ecosystem. Moderate SDIs from 34–54 result in increased measurable stress that begins to manifest itself in decreased health and diversity and threats to sustainability. High SDIs above 54 place the forest ecosystem at risk in many categories. Increased competition for light and nutrients, increased moisture stress in plants, increased outbreaks of insect and disease, and greater risk of destructive wildfires are examples of threats to sustainability.

There are a number of acreages on the NKRD that fall into moderate and high risk densities, as regards Schmid et al. (1994) stand density index risk ratings (Fig. 8). Over 60% of the ponderosa pine forest is moderate to high risk and 33% is high risk. That tree densities have increased radically on the NKRD in the past 100 years means little to most people. However, these increases in tree densities could pose major ecosystem management problems on the Kaibab Plateau. The forests of the Kaibab Plateau appear to be on a path similar to that of the Blue Mountains of Oregon (Sampson and Adams 1994). Forest ecosystems in the Blue Mountains have become so degraded due to high tree densities, that a national program has been implemented to save extensive forest watersheds from destruction by wildfire catastrophes (Sampson and Adams 1994).

In this paper we have described increases in overstory tree densities on the North Kaibab that appear unwarranted, especially in view of existing scientific knowledge. It would seem prudent for managers to initiate management actions to mitigate the ecosystem impacts of increased densities.

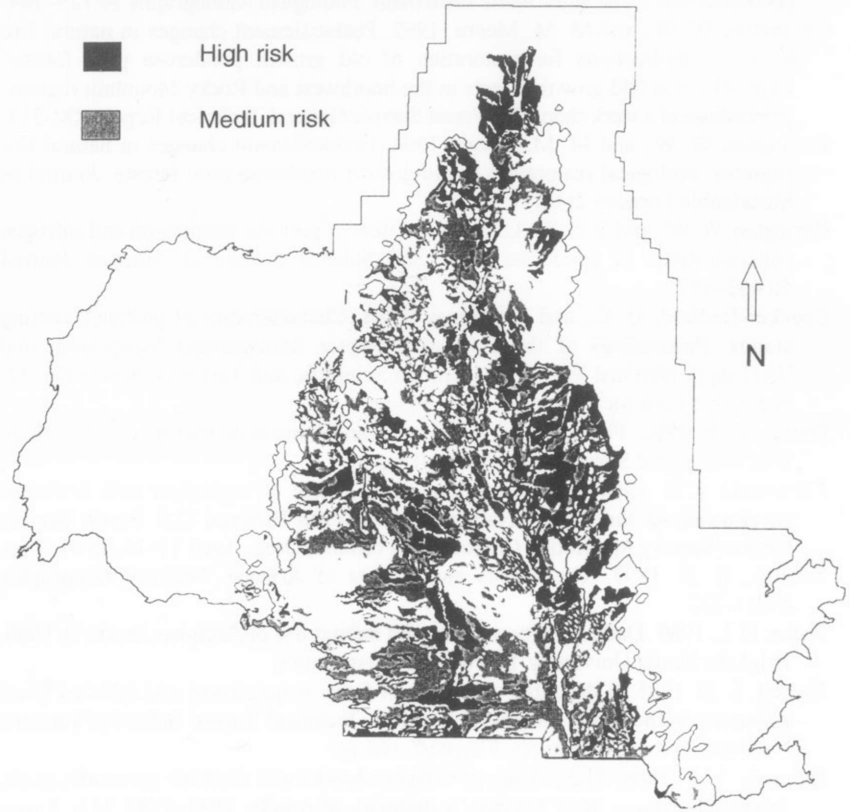

Fig. 8. Areas of the North Kaibab Ranger District (NKRD) classified as medium to high risk using stand density index as a relative measure of stand density.

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